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Influences of operating parameters on the aerodynamics and aeroacoustics of a horizontal-axis wind turbine

Sanxia Zhang^a, Kun Luo^{a,*}, Renyu Yuan^a, Qiang Wang^a, Jianwen Wang^{b,c},
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ABSTRACT

A computational framework used to evaluate the aerodynamics and aeroacoustics is developed and validated against the experimental data in the previous work. In the present work, the different operating parameters of inlet flow velocity, tip speed ratio and turbulence intensity have been considered separately. The aerodynamic performance, the vortex dynamics and the aeroacoustics of the full scale horizontal-axis wind turbine under different operating conditions have been investigated. And the analysis of the impact of different operating parameters is discussed. It is observed that the model has an extension to different conditions and it is sensitive and accurate for simulating the results of different condition parameters. According to the results, the wind with lower turbulence intensity will be better for the operating, and the wind turbine operation can be optimized by adjusting the rotating speed (TSR) according to the inflow wind velocity. In the end, a noise and power trade-off graphics has been proposed based on the wind turbine acoustics and performance results. With enough operating conditions available for reference, selecting the optimal operating parameters under specific operating conditions according to the noise and power trade-offs graphics becomes feasible.

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1. Introduction

Energy is a vital input for social and economic development in any country including China. With the agricultural and industrial activities in the country increasing, the demand for energy is also increasing. On the other hand, it is observed that there are growing concerns about global energy demand and environmental pollution [1]. In a positive and responsible attitude, China is actively fulfilling its obligations under the international environmental conventions. For many important international environmental conventions, China has formulated a proactive and actionable plan of action. According to the “13th Five-Year Energy Development Plan” in China [2], the proportion of non-fossil energy consumption will be increased to more than 15% during the plan from 2016 to 2020. In that regard, wind energy will play a significant role in the near future [3]. Wind energy has been developing rapidly in China, and the cumulative installed capacity of wind power in China exceeded

168 GW in 2016 according to the statistics [2]. China plans to speed up the development of wind power in the eastern and southern regions, where there is a need to improve low-speed wind turbine technology and micro-site selection level to promote decentralized wind power construction.

With the growing interest in decentralized wind power construction, small-scale wind turbines are an interesting option for household and small firms. To make such an investment more efficient, it is crucial for the wind turbine working conditions to be favorable. Therefore there is a need to research the operating characteristics under variable operating conditions and optimize the operating parameters of the wind turbine [4]. And the establishment of a cost-effective model to study the influence of parameters is needed. In addition, the noise is another vital problem that should be considered [5]. Since the sites are often located near rural areas, conflicts with the recreational life of people nearby often occur [6]. Noise is an annoyance factor at wind farms and hence there is a need for reliable methods to solve problem [7]. It is time consuming and difficult to conduct field measurement that contain a large variety of metrological problems [8]. Therefore it is

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作者: Zhang, SX (Zhang, Sanxia)^[1]; Luo, K (Luo, Kun)^[1]; Yuan, RY (Yuan, Renyu)^[1]; Wang, Q (Wang, Qiang)^[1]; Wang, JW (Wang, Jianwen)^[2,3,4]; Zhang, LR (Zhang, Liru)^[2,3,4]; Fan, JR (Fan, Jianren)^[1]

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摘要

A computational framework used to evaluate the aerodynamics and aeroacoustics is developed and validated against the experimental data in the previous work. In the present work, the different operating parameters of inlet flow velocity, tip speed ratio and turbulence intensity have been considered separately. The aerodynamic performance, the vortex dynamics and the aerodynamic acoustics of the full scale horizontal-axis wind turbine under different operating conditions have been investigated. And the analysis of the impact of different operating parameters is discussed. It is observed that the model has an extension to different conditions and it is sensitive and accurate for simulating the results of different condition parameters. According to the results, the wind with lower turbulence intensity will be better for the operating, and the wind turbine operation can be optimized by adjusting the rotating speed (TSR) according to the inflow wind velocity. In the end, a noise and power trade-off graphics has been proposed based on the wind turbine acoustics and performance results. With enough operating conditions available for reference, selecting the optimal operating parameters under specific operating conditions according to the noise and power trade-offs graphics becomes feasible. (C) 2018 Elsevier Ltd. All rights reserved.

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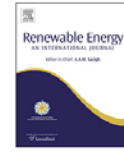
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评价指标

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Large-eddy simulation and wind-tunnel measurement of aerodynamics and aeroacoustics of a horizontal-axis wind turbine



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ABSTRACT

Large-eddy simulation of the whole three-dimensional vortex dynamics and noise radiation around a horizontal-axis wind turbine has been studied and analyzed together with wind-tunnel experimental measurement. A computational framework that takes into account of the true shape of the wind turbine blade geometry for calculating the aerodynamics and aeroacoustics is developed and validated against the experimental data. The LES results generally agree well with the experimental data in terms of both the aerodynamics and aeroacoustics statistics. The formation and development of the complex three-dimensional wake vortexes are captured and analyzed, and the aerodynamic noise is further studied based on the flow field using the FW–H method. It is found that noise generation and acoustic radiation are closely associated with the generation and evolution of these vortex structures. The blade tip region is the main resource area of the aero-noise and the acoustic radiation intensity of the rotor decreases rapidly downstream.

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1. Introduction

The aerodynamic research and wake flow analysis for wind turbines have contributed a lot to the success of modern wind energy utilization [1–3], and technologies for wind energy conversion have significantly advanced during the past few decades. The Horizontal-Axis Wind Turbine (HAWT) is the least expensive and clean way to make use of the wind power. As the interaction between the wind and the blade influences the efficiency, the design and development of more efficient and reliable wind turbines rely heavily on accurate prediction of aerodynamic behaviors and can benefit significantly from a good knowledge of parameters related to the wake [4,5]. However, some environmental and social problems still remain unsolved, and the wind turbine noise becomes the most serious issue among them [6]. The wind turbine noise, especially the aerodynamic noise is even hindering the global use of the wind turbine. It is thus very important to understand the noise source mechanisms, depending on the rotor

aerodynamic characteristics and the operating conditions for a wide range of the rotor's frequency spectrum [7,8].

Methods of different levels of complexity to investigate the aerodynamic and aeroacoustic behaviors of a wind turbine rotor have been developed. These methods include the Blade Element Momentum (BEM) theory, the wind tunnel experiment, the field experiment and the computational fluid dynamics (CFD) [1]. The BEM theory that proposed by Glauert is the most classical approach for the aerodynamic design of wind turbine [9]. However, it requires adding a number of amendments to the project [10]. The BEM theory occupies fewer resources in the calculation and it would be relatively more rapid, but it cannot get the details of the blade surface pressure distribution, and cannot provide accurate aerodynamic load data for the structural analysis of wind turbine blades. On the contrary, CFD simulation is a cheap and efficient way to provide valuable quantitative insight into the aerodynamic and aeroacoustic behaviors of flow around wind turbine. It has helped the industry become more efficient and productive and has enabled new designs and levels of efficiency not possible before [11,12].

CFD modeling and experiment have both advantages and disadvantages. They can be complementary to each other and one can expect more effective understanding of the phenomenon. The CFD

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